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DEEP CORE DRILLING: ELECTRO-MECHANICAL OR THERMAL DRILL?

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ABSTRACT

In 1977/78 at Dome C, Antarctica, it was not possible to drill deeper than 905 m because of hole closure. The thermal drill has subsequently been modified to drill deeper in a fluid filled hole. Simultaneously, we have developed an electro-mechanical drill which employs a centrifuge device for separating chips and drilling fluid. Both sets of equipment are described ~~here,~~ as well as the main results obtained in the first tests made in Adélie Land in 1981/82.

INTRODUCTION

The thermal drill used in 1977/78 at Dome C, to core to a depth of 905 m, has been modified in order to drill in a fluid filled hole. The main advantage of this thermal equipment is to give runs of up to 6-8 m without difficulty, but its penetration rate (6-7 m/h) is relatively low. Due to the high electrical power needed at the head (5-6 KW) and auxiliary requirements, the number of cable conductors is high, resulting in a rather large cable diameter.

An electro-mechanical drill which requires about 1 KW to rotate the cutters and which has a penetration rate of 20-40 m/h appears to be a good alternative. However, for deep drilling, it is necessary to have runs as long as possible. In a mechanical drill, this introduces a problem associated with the transport of cuttings. To increase the efficiency of chip transport, we developed a system using a centrifuge.

A first test was made this year in Adélie Land for both drilling systems.

THERMAL DRILL

The unit (Fig. 1), which was used in Adélie Land (to 304 m) and on a temperate glacier (Gillet, *et. al.*,1976), has also been used at Dome C (to 905 m), in the Glacier d'Argentieres (to 245 m) and again in Adélie Land (to 348 m). For this last drilling operation in 1981/82, some modifications were made to the drill:

(1) The electrical insulation of the bare wire was installed with two types of support. These are, a stainless steel crown covered with a thin deposit of chromium oxide and a machined ceramic fixed in a hollow stainless steel crown.

(2) The thermal insulation required in the suction tubes in the core barrel and on the melt tank is produced by applying a layer of epoxy resin on the inside wall of the tubes by a centrifuge process.

(3) The OD of the drill was increased to 140 mm to be compatible with the hole produced by the electro-mechanical drill.

To work in a fluid, the vacuum pump was replaced by a small, 30 W, 220 V vibration pump. The flow may be varied from 5 to 300 ℓ/h but is generally adjusted at 40 ℓ/h. It is located at the top of the melt tank, so that no water flows through it.

Heating of the suction tubes and of the melt tank was increased and can be varied separately from 0 to 350 W for the tubes and from 0 to 500 W for the tank (Fig. 1).

The maximum power is used at the beginning of each run until the permanent water circulation is established. Three different temperature measurements

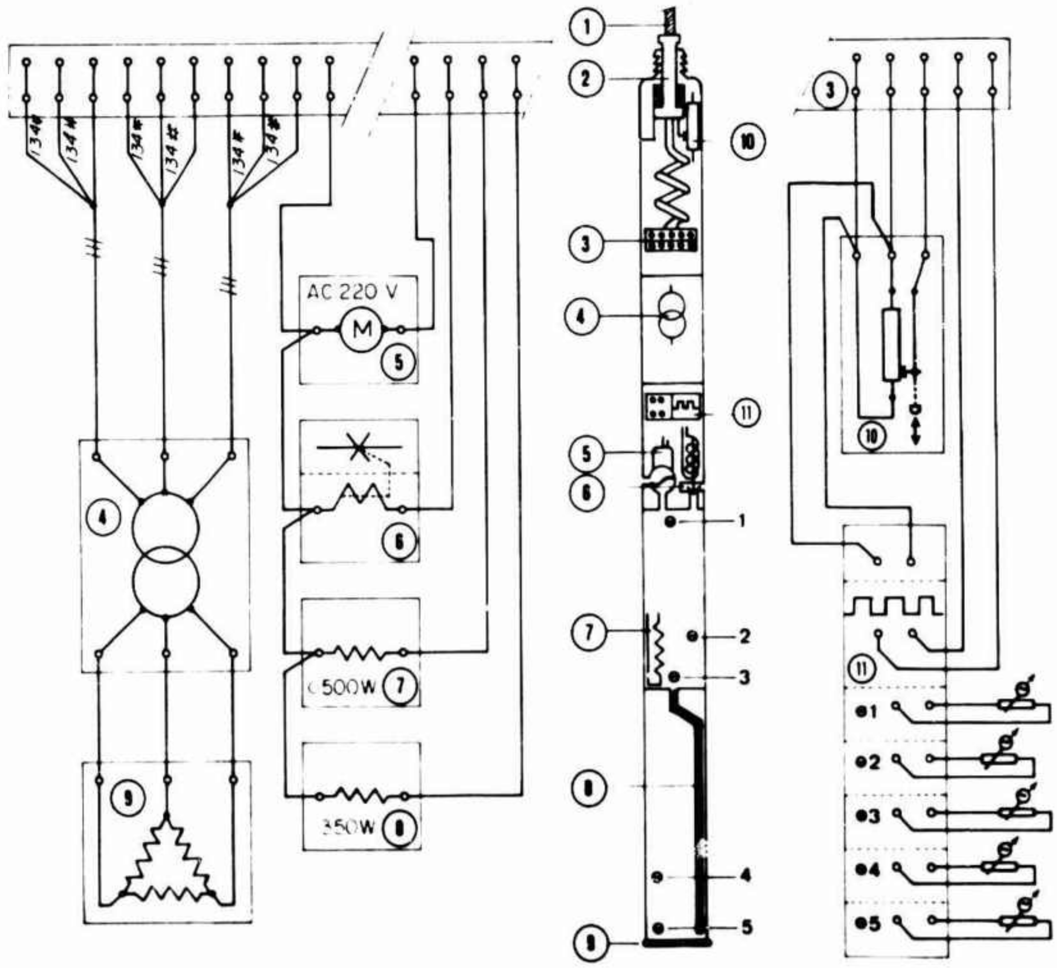

Figure 1. Schematic diagram of the thermal drill unit (electrical diagram). (1) Electro-mechanical cable. (2) Cable termination. (3) Junction box. (4) Transformer. (5) Pump. (6) Valve. (7) Heating element (melt tank). (8) Heating element (tubes). (9) Bare resistance wire. (10) Suspension. (11) Electronic switch (for θ measurements). (θ_1) Top of melt tank (water level measurement). (θ_2) Melt tank. (θ_3) Top of the suction tubes. (θ_4) Drilling fluid. (θ_5) Head.

were made at the head, top of the suction tubes and the melt tank. The signals are transmitted consecutively, to the surface through two conductors, using an electronic switch. It should also be worthwhile to measure the temperature of the drilling fluid near the head, as this measurement would be an indirect indication of the water level in the hole.

The cable was the same 1000 m electro-mechanical cable already used at Dome C (16 mm ϕ; 6 conductors at 1.34 mm^2 13 conductors at 0.93 mm^2). For deep drilling, we are planning to use a cable with 8 conductors at 1.34 mm^2 with a bifilar line in the core. The cable diameter is 16 mm and the weight 930 Kg/Km. For heating of the head, 2 x 3 conductors would be used at 1000 V. Two conductors would be used for auxiliaries and the bifilar line for telemetering.

RESULTS

In 1981/82, we drilled a dry hole to 329 m. Kerosene was then put in the hole before drilling continued to 348 m depth.

With a 2.8 m length core barrel and runs between 2 and 2.5 m, we had no problems circulating the water. It seems possible to increase the barrel length to 6-8 m without any major difficulties.

The penetration rate (Fig. 2) is the same as in a dry hole and varies from 5 to 7 m/h, corresponding to power on the head from 3.5 to 5 KW.

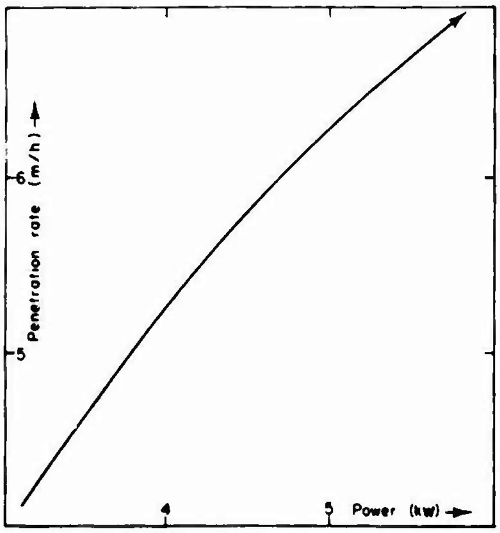

Figure 2. Penetration rate as a function of power on the head.

Core quality is excellent. We obtained completely transparent cores without any fractures, whereas, a few meters before, we had foliated cores as previously obtained in the 905 m dry hole at Dome C.

The amount of melt water recovered during each run, is between 14 and 18 ℓ. The diameter of the cores is the same as in a dry hole and is about 115-116 mm.

ELECTRO-MECHANICAL DRILL

This unit (Fig. 3) is 140 mm in outside diameter and 8 m long. The termination and anti-torque sections of the shallow electro-mechanical drill is utilized. A 380 V, 3 phase, 3.7 KW, 2800 RPM submersible electric motor rotates the centrifuge basket which is made from a 110 mm diameter, 3 m long aluminium tube. One hundred holes are drilled in it and it contains a stainless steel, 0.5 mm thick filter. At the lower end, a propeller with three adjustable blades, is used as a circulation pump and gives a satisfactory vertical flow to the chip loaded fluid. The tube is connected to a 3 stage gear reducer (1:27) giving a rotation speed of 105 RPM to the core barrel. The chip loaded fluid flows to the inner side of the centrifuge basket through a 40 mm diameter hollow shaft in the gear reducer. The head has three round cutters. The chips produced, are

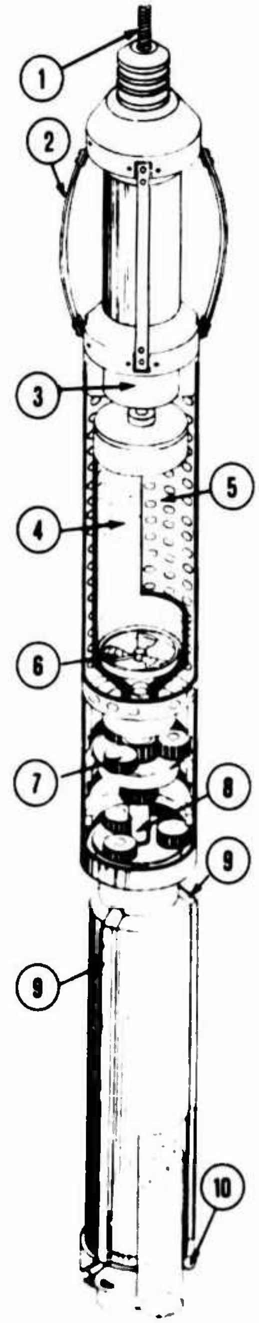

Figure 3. Schematic diagram of the electro-mechanical drill. (1) Electro-mechanical cable. (2) Springs. (3) Submersible motor. (4) Filter. (5) Centrifuge basket. (6) Propeller. (7) Gear reducer. (8) Hollow shaft. (9) Rectangular tubes. (10) Cutters.

transported by the fluid through three rectangular tubes soldered onto the 118 mm (ID) x 121 mm (OD) stainless steel tube of the core barrel. This rectangular shape reduces the width of the cutters, and, as a result, the quantity of chips to be removed. The diameter of the core is 115 mm and the diameter of the hole is 143 mm.

RESULTS

Due to some defect in the core catchers, it was not possible to retrieve cores. Nevertheless, the centrifuge device was tested. We obtained a 3 cm thick hollow cylinder of compressed chips with a density of about 0.6 Mg m^{-3}. The regular distribution of these chips along the tube indicates that it will be possible to store an amount of chips allowing runs of up to 3 m to be made.

However, the power consumption was very high because of the speed of the centrifuge assembly in the fluid. This speed, causing frictional drag, has to be reduced. Some laboratory tests need to be made in order to determine the optimum value.

CONCLUSIONS

After this field season in Adélie Land, it appears that the thermal drill described here can be modified for deep drilling. The size of the 4000 m long cable is compatible with the logistics constraints. The minimum time needed to drill to 3500 m may be estimated as shown in Table 1.

Table 1

Activity	6 m run	8 m run
Penetration rate (6 m/h)	583 h	583 h
Winching (at 60 m/min)	568 h	425 h
Accumulated time spent at the surface (est 0.5 h/run)	291 h	218 h
Totals	1442 h	1226 h

These figures (50-60 days) show that it is possible in principle to drill to 3500 m in a single summer season.

The electro-mechanical drill used this year is an interesting device, but more tests are needed before its deployment in a deep drilling operation.

Table 2 shows that the time needed to drill to 3500 m is very dependent on the length of each run.

Table 2

Activity	2 m run	3 m run
Penetration rate (30 m/h)	117 h	117 h
Winching (at 60 m/min)	1702 h	1135 h
Accumulated time spent at the surface (est 0.4 h/run)	700 h	467 h
Totals	2519 h	1719 h

Table 2 indicates that 72 -105 days would be needed to drill to 3500 m with the electro-mechanical drill.

These results encourage us to build a thermal drill with a 4000 m cable and associated winch. If the final tests of the electro-mechanical drill are satisfactory, and, especially if the run length can be increased to over 3 m, we will then use it interchangeably with the winch and cable system of the thermal drill.

ACKNOWLEDGMENTS

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